

TABLE 4.—*Maximum wind velocity, in miles per hour, for a five-minute period, midnight to midnight, at Weather Bureau anemometer, and time of occurrence as referred to the time of shift from southwest to west.*

Date.	Maximum velocity.	Direction at time of maximum.	Time relative to shift.
1916.			
Jan. 2.....	58	w.....	5½ hours later.
5.....	60	nw.....	3 hours later.
10.....	50	sw.....	4 hours earlier.
10.....	50	w.....	On time.
13.....	76	w.....	4 hours later.
Feb. 7.....	70	w.....	No evidence.
Mar. 7.....	80	w.....	1½ hours later.
Apr. 14.....	56	w.....	10 minutes later.
Oct. 25.....	60	w.....	50 minutes later.
Nov. 23.....	52	w.....	1 hour later.
24.....	72	w.....	No evidence.
Dec. 5.....	68	w.....	On time.

It would be interesting to know just why the winds that reach the Coast Guard anemometer in full force from the lake are retarded nearly as much as are those from directions which are sheltered by the city. It might be suggested that the retarding effect of the city extends to windward because of the banking of the wind; or that the velocity of southwest and west winds at the level of the Weather Bureau anemometer is increased by the presence of the city or of the building, the air that would ordinarily flow at the lower levels being constrained to flow with the layers normal to the height of the anemometer, thus rendering necessary an increased velocity in order that the greater volume of air may pass in the same time. The evidence furnished by the northerly and southerly winds that suffered no obstruction to their flow, either before or after they had passed the Coast Guard anemometer, indicates that in the case of southwest and west winds the Coast Guard anemometer is slowed down, rather than that the Weather Bureau anemometer is speeded up by the presence of the city. If this is correct, then the Weather Bureau anemometer is more nearly representative of the true velocities over the lake at the height of the Coast Guard anemometer than is the Coast Guard anemometer itself, even though the latter is on the lake shore.

A similar comparison made at Chicago in 1911, showed lake winds stronger at the Life Saving Station than on the Federal Building, and land winds nearly the same at both stations; but in this instance the exposure on the Federal Building was admittedly faulty.¹

551.46.68

SOME NEW INSTRUMENTS FOR OCEANOGRAPHICAL RESEARCH.

By DR. HANS PETTERSSON.

[Dated: Göteborgs Högskola, Oceanografiska Institutionen, Feb. 7, 1917. MS. received Mar. 29, 1917.]

When considering the remarkable progress made by meteorological science during the last decades, one should not overlook the fact that this advance has been made possible by a parallel and not less remarkable development in the technique of the science, viz, of its instrumental resources. Both as regards general meteorology and perhaps still more within such specialized

branches as the study of radiation or high upper air altitude research (where American scientists take a prominent part) we owe the wonderful equipment of modern research to the inventive genius of men like Cleveland Abbe, R. Assmann, C. G. Abbot, C. F. Marvin, etc. As to recording instruments of all kinds the meteorologist of to-day is perhaps better equipped than any other student of natural phenomena, and certainly much better than the followers of the younger sister science of oceanography.

In a previous note in this REVIEW (see issue for June, 1916, 44: 338) I have tried to set out the reasons for a close cooperation between meteorologists and oceanographers in an extensive study of the North Atlantic Ocean, of the variable physical conditions of its surface sheet, and of the influences direct and indirect which these latter undoubtedly exert on the weather and the climate of the surrounding continents. In the following pages I intend to give a brief description of some novel instruments which highly facilitate the collection of oceanographical data.

Ever since scientific marine research was for the first time taken up on a broad basis by the International Council for the Study of the North Sea, it has become more and more manifest that if results of any practical value for the fishing industries or for meteorological forecasts are to be derived from this work then the net of investigation must be drawn tighter, the frequency of observations increased, and the field of research expanded. This is specially the case in coastal regions where our investigations have proved physical conditions in the fluid element to be almost as variable as they are in the atmosphere. From our research station Bornö in the Gullmarfjord (west coast of Sweden) we possess unique series of continuous hydrographical observations (salinity and temperature measurements at different depths) which have been made daily for over seven years with few breaks. The results prove that the different water layers, differing in density from each other, instead of being at rest are in a state of almost incessant motion with large displacements both vertical and horizontal taking place in a very short time. Thus the boundary surface between two water layers may, from one day to the next, fall by 10 or even 20 meters, which of course involves a radical change in the hydrographical situation, millions of tons of brackish water being swept out to sea and replaced from below by a simultaneous invasion of saltier water of North Sea origin. At the suggestion of the author a series of synoptic parallel observations of these internal movements, previously only studied at Bornö, were carried out at five different localities during November, 1915, by the Swedish Hydrographical-biological Commission. The results prove that the more considerable internal movements are of a general character and that parallel displacements of the boundary occur almost simultaneously at all the different points of observation.

As regards the practical importance of these movements, they must obviously have a profound influence on fish life. O. Pettersson has repeatedly found particularly large upheavals of the boundary surface to coincide with rich catches of herring during the winter fisheries. The author has compared the above-mentioned hydrographical series with statistics from the local fishery and found that the chances of catching mackerel at Bornö in summer are from four to six times better when the boundary surface of 30 per mille salinity is below its average level than in the opposite case.

¹ Cox, H. J. & Armington, J. H. The weather and climate of Chicago, Chicago, Ill., 1914 (Geogr. Soc. Chicago, Bull. 4), pp. 286-289.

Self-recording densimeter.

In order to follow these internal movements more closely O. Pettersson in 1909 constructed a recording densimeter by means of which the hidden displacements of the boundary surface are made to draw their own

is completely filled with sea water and a little paraffin oil, and is balanced against a counterpoise of solid metal (*B* in the figure) so that it barely floats in water of about 30 per mille salinity at 10°C. Therefore when the corresponding boundary surface rises or falls it will carry the float upward or downward, the movements

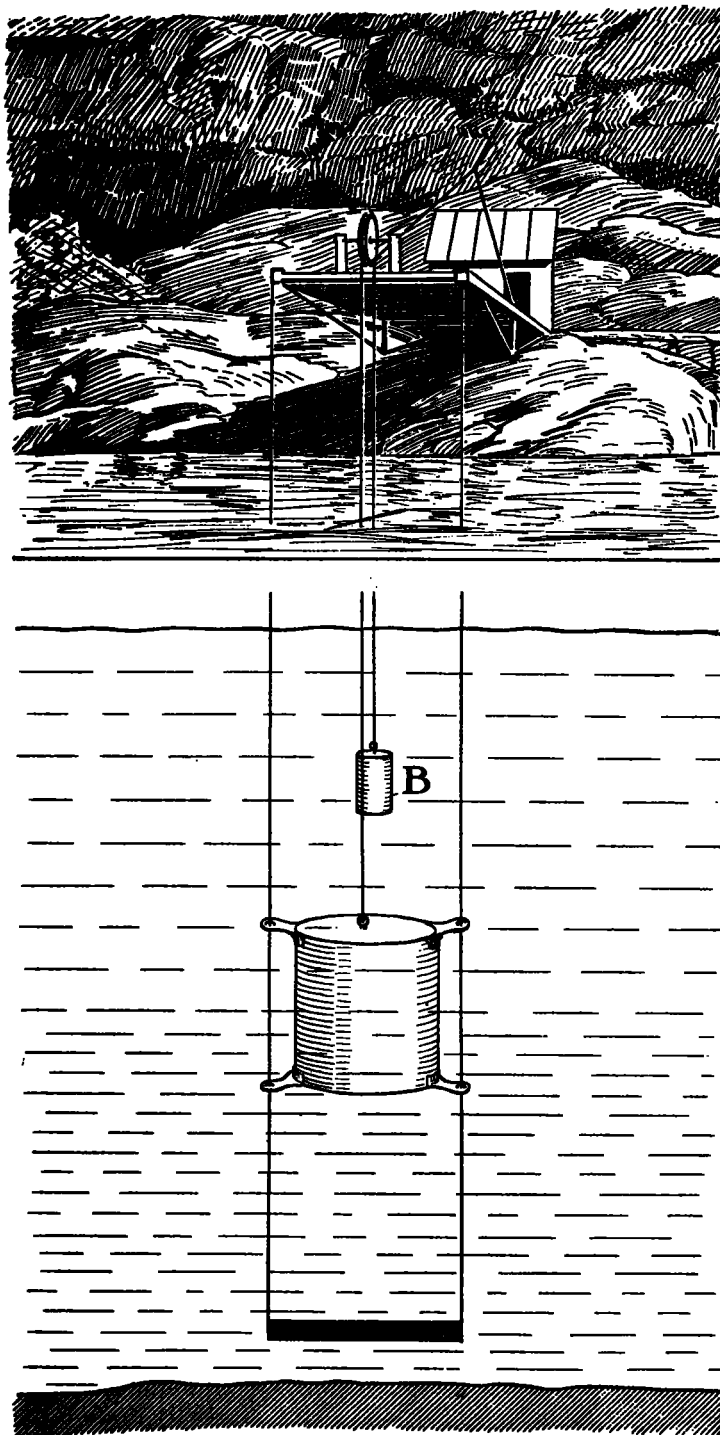


FIG. 1.—O. Pettersson's recording densimeter, out-board portion.

record. The main features of the arrangement are sketched on figure 1.¹ A large cylindrical copper float is free to move vertically from the surface to the bottom at 30 meters between two guide wires of brass. The float

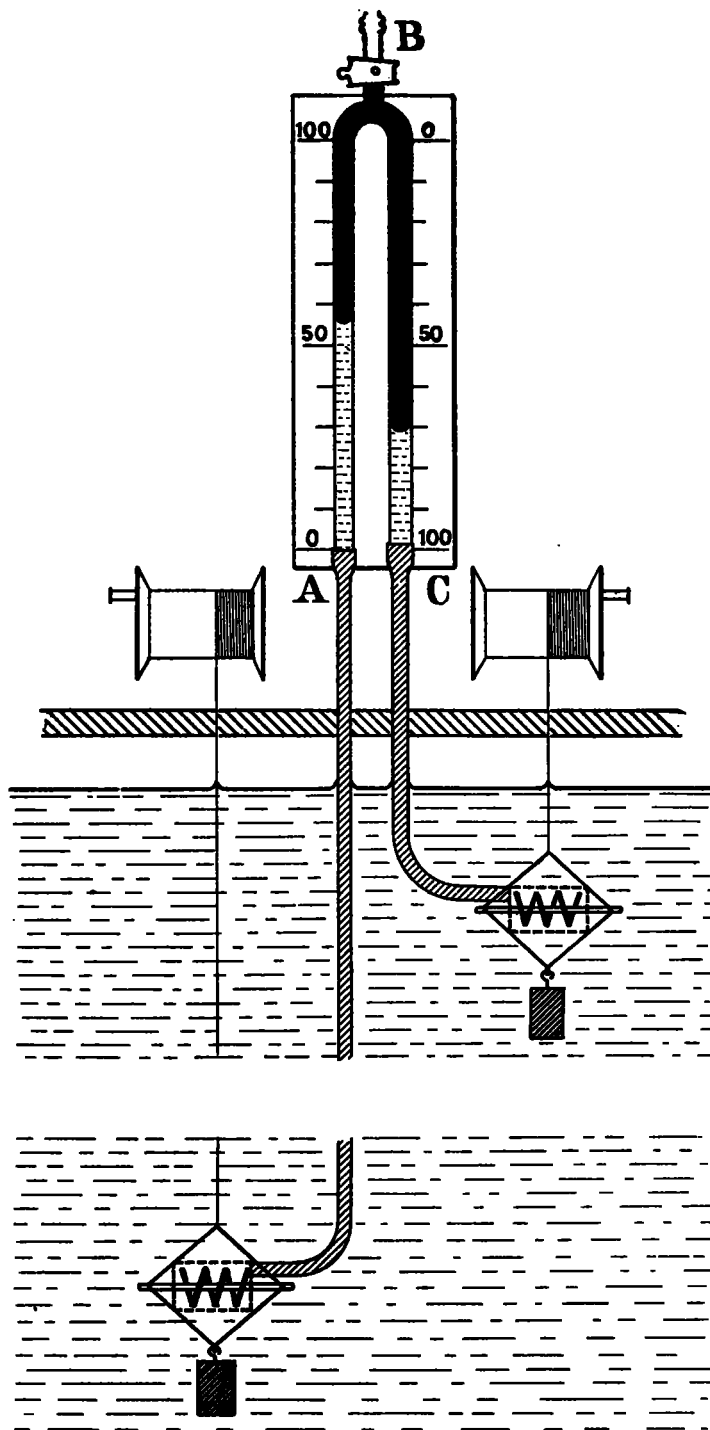


FIG. 2.—H. Pettersson's hydrostatic densimeter.

being transferred to a wheel on the bridge serving as support, and from there to a recording pen and drum on the shore. It is not an uncommon experience to find the float one day floating at the surface in clear salt water and next day out of sight beneath a sheet of brownish water of low salinity, 10 meters or more in depth.

¹ Figs. 1-6 reproduced by permission of the editor of *Annalen der Hydrographie und maritimen Meteorologie*.

The record from this instrument, the first by which vertical movements in the sea can be studied, has for years been checked by daily titrations on water samples from different depths and it represents a most valuable material, both for hydrobiological and hydrodynamical research. Thus boundary waves, both of tidal origin and generated by seiches, have been observed and studied theoretically by Nils Zeilon.³

A modification of the above instrument intended for work in the open sea, combined with a thermograph, was devised by the author two years ago and ordered abroad, its completion being unfortunately still delayed by the war.

Hydrostatic densimeter.

In order to get a simpler and less expensive arrangement for the study of similar internal movements the author has constructed and tested an entirely novel kind of densimeter based on the hydrostatic principle (see fig. 2). From a vertical, inverted U-tube of glass, ABC, 10 mm.

with the outer water, as well as to prevent any disturbance in equilibrium by the motion of the surface waves and any aspirating effects of horizontal currents.

The instrument is inexpensive, reacts instantly to internal movements, also to such of very small amplitude, and may therefore be used also for the study of Helmholtzian waves. Moreover, the readings are extremely simple, the actual position of the boundary surface being found by a glance at an instrument on the laboratory wall with as little trouble as that of reading the air temperature. It would obviously be of great advantage if the instrument could be made self-recording, but this involves considerable technical difficulties.

In figure 3 the upper curve shows graphically the plotted readings taken from a similar instrument at Bornö during July 27–31, 1916, compared with the simultaneous curve from the recording densimeter. The agreement is seen to be perfect.

Thanks to the kind assistance of Capt. G. Ridderstad, commanding our research vessel, the *Skagerak*,

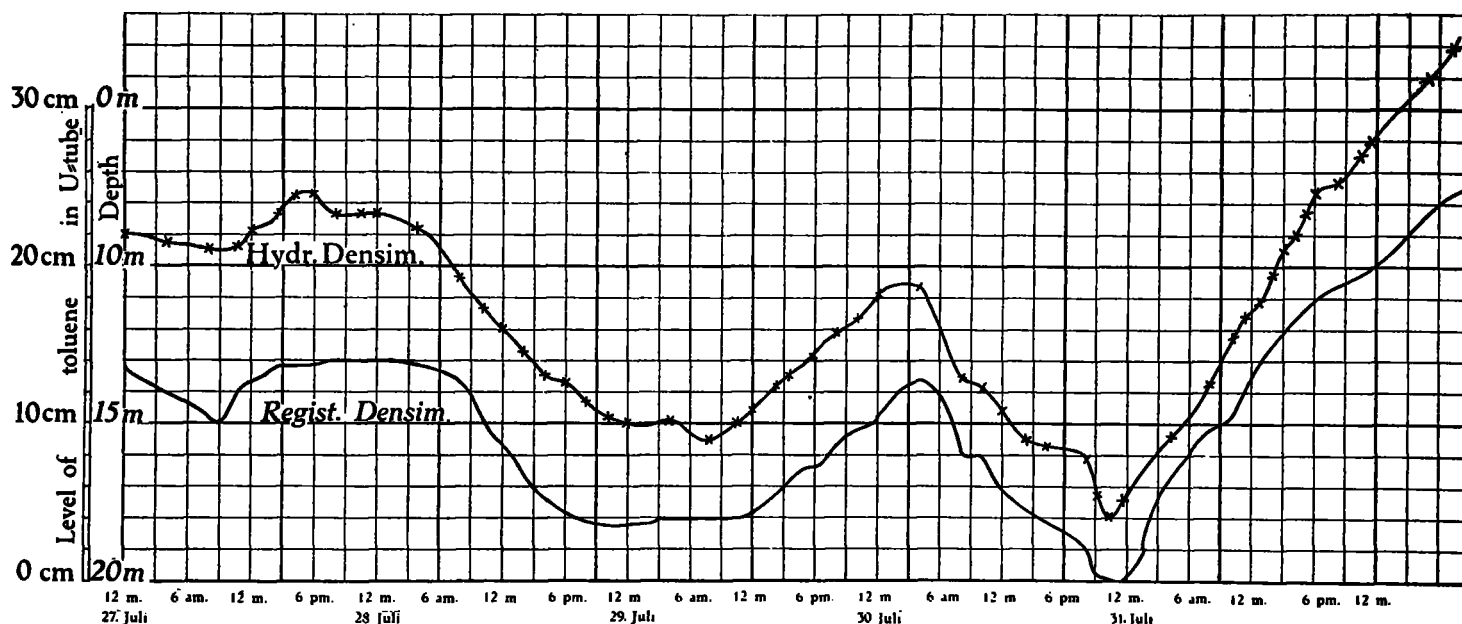


FIG. 3.—Readings of the hydrostatic densimeter (upper curve) compared with the simultaneously recorded curve from the recording densimeter.

wide and 100 cm. long, two tubes of rubber or metal lead down to depths of say 2 meters and 25 meters, respectively. The whole system is filled air-free with salt water of a known density, d_r , only the upper half of the U-tube containing a liquid of lower density d_L (toluene colored red with azoamidobenzol). If the average density of the water in the fiord between 2 and 25 meters just equals d_r then the toluene will be at rest at equal heights in both branches of the U-tube. But if the salinity in the fiord is increased by an upheaval of the boundary surface, then the toluene becomes pressed over from the "deep" to the "shallow" branch of the U-tube. The meniscus between the toluene and the water in the U-tube, which can be read to within 1 mm. on a vertical scale, will therefore in general rise or fall in a manner exactly parallel to the movements of the boundary surface in the fiord, but on a scale reduced in the proportion $1:r$ where $r = (d_r - d_L)/(d_{25} - d_2)$, d_{25} and d_2 being the density of the sea water at 2 meters and at 25 meters below the surface. Special arrangements at the lower orifices of the rubber tubes serve to retard the intermixture of their contents

the instrument has also been tested on board during a week in July, 1916, when the ship lay anchored at the entrance to the Gullmarfiord. The results are highly interesting as they reveal the existence of rythmical oscillations in the boundary having a sharply defined period (15 minutes).

The author hopes that a slightly modified type of the hydrostatic densimeter may be installed on several lightships anchored off the coasts of Denmark and Sweden.

Water bottles for direct measurements of the density.

In order to simplify as far as possible the technique of hydrographical soundings where no high accuracy is necessary, the author has attempted to construct a water bottle which will at a glance give a rough indication of the salinity and the temperature of its contents.

This instrument is intended mainly for the use of fishermen who may derive information of practical value from similar observations. The water bottle, which can be made to inclose hermetically a volume of the water at any desired depth by means of the ordinary closing

³ Svenska Hydrografisk-Biologiska Kommissionens Skrifter, V.

arrangement with a messenger, has a cylindrical body of some transparent material, glass or "cellon." Within the latter there are, say a dozen of glass balls of different colors, inset pieces of netting at the top and at the bottom of the glass cylinder preventing their escape when the bottle is open. The glass balls have been so balanced as to float in waters of different density, say one at density 1.027, the next at 1.026, and so on. On a simple

thermometer mounted axially within the water bottle the temperature can be read to within 0.5 degree (C.), and by counting the number of glass balls afloat or those lying on the bottom of the water bottle when the latter is brought to the surface, one finds the salinity to within say 0.0005. The instrument is extremely simple and has been used with good results by two common fishermen during reconnoitering cruises after herring. Owing to the peculiar hydrographical conditions in stratified waters, the position of a boundary surface may be located with the same accuracy by the aid of such an instrument as from a series of water samples taken at say every fifth meter and analyzed by titration to within 0.00002.

The instrument just described would obviously be greatly improved if it could be made to give more exact readings of the salinity. I have constructed another water bottle answering to this demand, sketched in figure 4. The body of this water bottle, which in other respects closely resembles the preceding, is narrower and longer and is graduated by a number of parallel rings, one for every fifth millimeter. Instead of the numerous balls, it contains a single cylindrical float of glass, *F*, which is held tight by three clamps at the lower end of the water bottle when it goes down open, but becomes released automatically as the bottle is closed. The float then rises in the cylinder to a height which can be read to within 1 mm. This height is brought into direct proportion to the density of the water, owing to an automatic adjustment of the buoyancy of the float by means of a very fine chain of gold or of gilt metal attached to its lower end. This latter device was suggested to me by my friend Dr. Anders Ångström, of Upsala.

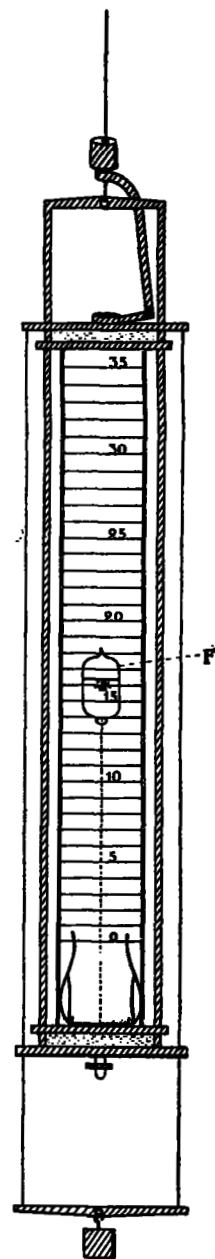


FIG. 4.—H. Pettersson's precision direct-reading density water bottle. *F*—float with compensating chain.

With a float measuring about 40 cu. cm. in volume and a chain weighing (submerged) 24 mg. per cm., a rise of 1 mm. by the float corresponds to an increase in the density of the water of 4 in 100,000 or a change in the salinity of about 0.00006. For ordinary investigations in the upper layers of coastal waters this degree of accuracy is quite sufficient. The temperature is measured on a sensitive thermometer inserted through a hole in the lid. For exact measurements of the temperature of the water in situ the instrument has to be combined with a reversing

thermometer. At depths exceeding a couple of hundred meters neither of the two last instruments can be used, owing to the high pressure on the bulbs or on the float.

Areometer with chain.

The automatic adjustment by means of a fine chain attached to the float may also be used for ordinary areometric purposes. In fact, the arrangement represents an almost ideal solution to the old demand for a practical areometer of total immersion. All the errors and corrections caused by surface tension involved in the use of ordinary areometers are avoided with the chain areometer. The only source of error (besides air bubbles and nonhomogeneous temperature in the water) is due to the chain taking up an irregular position, as when it hangs curved instead of depending straight down from the areometer with a sharp bend at right angles where it touches the bottom of the vessel. By gently tapping the glass vessel the chain can easily be brought to a correct position before readings are taken.

The sensitiveness of the arrangement, which may be made excessively high, depends on the size of the float and the weight of the chain and is limited only by the difficulty of excluding temperature disturbances.

For readings of moderate accuracy, 1 in 10,000 or even 1 in 20,000, the float may be of ordinary glass and the vessel containing it a simple glass tube, preferably with outlet below (and with gimbal suspension for work on shipboard). An instrument of this kind has just been tested with good results, also in rough weather, by one of my students, Mag. Sjöstrand, during a short cruise with the *Skagerak*.

[FIG. 5—Received too late to be included.]

If a high degree of accuracy is desirable, say of 1:50,000 or more, the float must have a volume of about 100 cu. cm., and should be made of silica in order to avoid corrections for the thermal expansion of glass. Also the measurements should then be made within a Dewar flask to eliminate as far as possible all temperature disturbances. Figure 5 [not reproduced] shows an instrument of this type used by the author.³ With the aid of a similar instrument for the deeper samples and for those demanding a higher accuracy, and with a water bottle of the type in figure 4 for the other water samples, the hydrographical soundings of an expedition may be carried out with a minimum of labor and without the necessity of storing any water samples for titration ashore.

An important point with regard to similar instruments is their "range," i. e., the interval of density over which they may be used. With instruments of moderate accuracy or with the water bottle, the position of the float may vary by about 350 scale units which, if the sensibility is taken to be 1:20,000 corresponds to a range of 1:60, say, from $\delta = 1.010$ to $\delta = 1.026$. This range again answers to a maximum interval in salinity of about 20 (not considering the influence of temperature variations) which meets all the requirements of an ordinary hydrographical expedition.

With high-precision instruments the total vertical displacement of the float can not very well be increased beyond 300 mm. If the accuracy is 2 in 100,000 per mm., the range will be about 1:160, or, say, from $\delta = 1.022$ to $\delta = 1.028$, which is again sufficient in most cases (for bottom

³ The drawing for fig. 5 and the MS for Table 1 were sent by the author at a later date than the balance of the article here published, but the mails failed to reach the editor in time for this issue. See issue for May, 1917.—C. A., jr.

layers in coastal regions as well as for measurements in the open ocean).

Obviously the range of the instrument can in both cases be extended a multiple of times by attaching to or detaching from the float standardized weights of platinum or quartz.

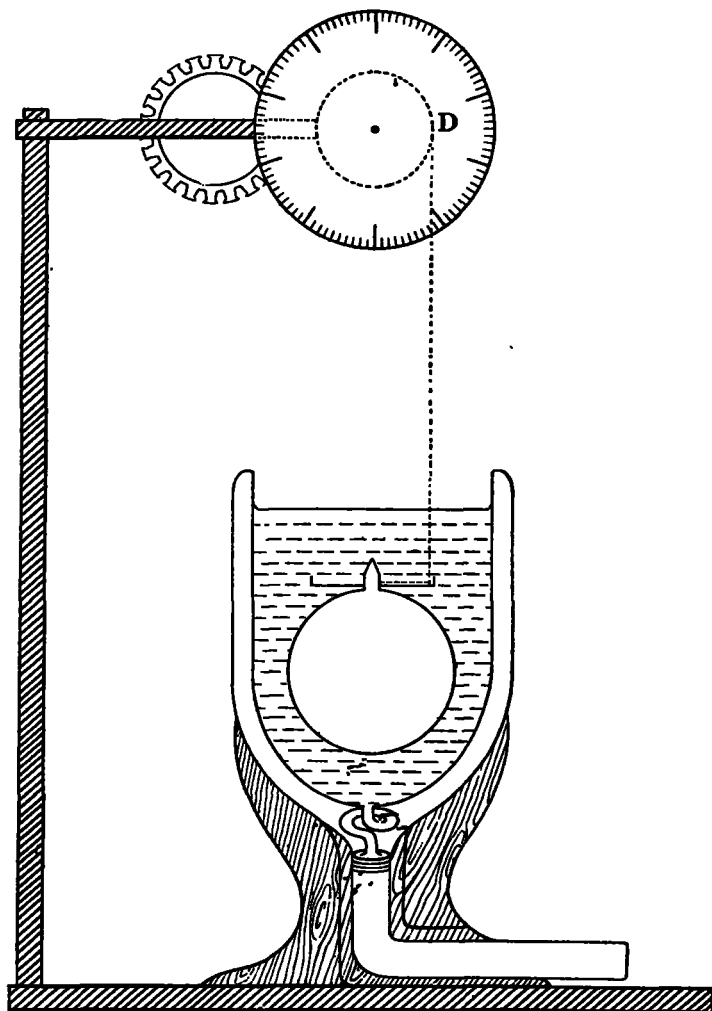


FIG. 6.—H. Pettersson's precision chain-compensated areometer with overhead chain.

A disadvantage of the instrument in figure 5 is the large amount of water required for each measurement, the capacity of the vessel being some 800 cu. cm. Acting on a suggestion by O. Pettersson that the chain may as well be let down on the float from above as depend from it to the bottom of the vessel, the author has had constructed an instrument of the type shown in figure 6. The spherical float is always brought back to its zero position by allowing a suitable length of the chain to be accumulated on a small tray attached to the top of the float, by unwinding the chain from a cylindrical drum with a spiral groove. With a float of 150 cu. cm. (sensitivity 1 in 80,000) the net capacity of the Dewar vacuum vessel is only 300 cu. cm., and the range 1:80, the total length of the chain available for measurements being 100 cm.

Recording current meter.

It is technically a most difficult problem to measure currents in the sea at different depths, even with a moderate degree of accuracy. A considerable number of

different current meters have been constructed for that purpose. However, also in this case, it has been found desirable for many purposes to keep up the observations for some time, repeating the measurements at regular intervals of time, as for example, when the tidal element of the currents is to be studied. With ordinary instruments such observations are extremely laborious and the strain on the human observers very great. The only successful recording current meter hitherto constructed is that invented by O. Pettersson (modified and improved by the author). Figure 7 conveys an idea of this instrument (vertical section).⁴

A cylindrical envelope of brass, provided with a large rudder which keeps the direction of the current, is kept hermetically closed by a lid and contains the registering apparatus, two opaque glass disks D_1 and D_2 , each with a row of numbers round its circumference. At every thirtieth minute those numbers, which happen to be before the aperture of a tiny camera are photographed by a flash from an electric lamp L_1 on a film slowly moved by clock-work. One of the disks carries two compass needles whereas the other disk is turned round by the current outside, acting on a current wheel W below the cylinder. From this wheel the movement is transferred to the interior and to the disk by means of two astatic magnets M_1 and M_2 , one inside the other outside, the magnetic force acting straight through the solid brass bottom of the cylinder (no leakage). Each photogram on the film therefore gives two numbers, one representing the average velocity of the current during the last half hour, the other showing its direction at the moment of exposure.

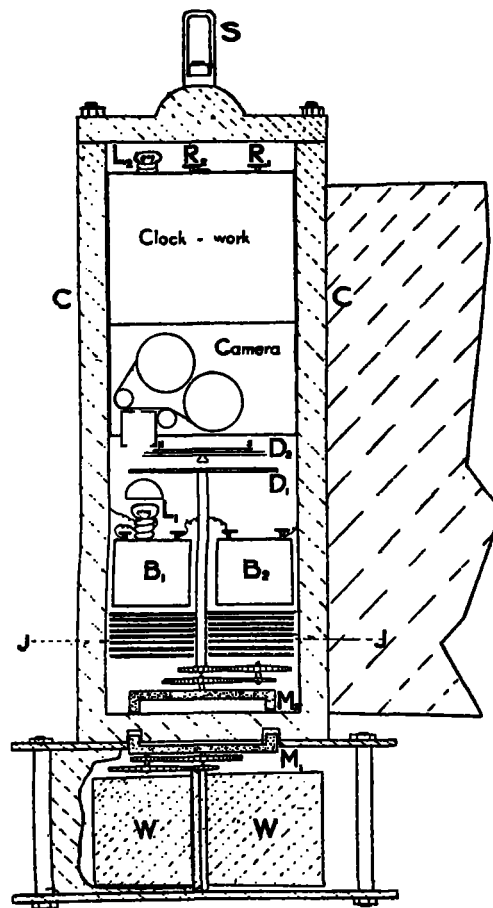


FIG. 7.—The Pettersson recording current meter for deep-sea exploration.

⁴ Pettersson, H. A recording current meter for deep-sea work. Quart. Jour., Royal met'l. soc., London, 1915. Fig. 7 reproduced by permission of the editor of that journal.

The current meter works automatically during a fortnight and may be left for that time unattended suspended from one of G. Ekman's submarine buoys.⁴ By this mode of suspension, first suggested by the author, one avoids all the errors usually inherent in the ordinary measurements from an anchored ship and due to the proper motion of the latter. The Ekman buoy, by its double anchorage, is kept at a depth of say, 5 or 10 meters below the surface and there stands as firmly as a rock unaffected by the waves and currents of the surface.

A few of these current meters thus anchored in the Strait of Florida or off the coast of Formosa would serve to keep under observation and to record the amount of water carried northward; thus it would be possible to determine the possibility of using such information in making seasonal forecasts of the temperatures over the eastern United States and Europe, or over Japan.

Conclusion.

Notwithstanding the brilliant results gained through individual efforts like the cruises of Sir Frithiof Nansen or of Johan Hjort and Sir John Murray, the vast field of research offered by the ocean calls for international cooperation on a large scale, if the desired harvest of useful results shall be reaped. The following lines for this work appear to the author as particularly worthy of attention:

I. The existing international network of meteorological observations, suspended during the war, should be extended also over the oceans by means of regular observations from an adequate number of transoceanic liners, reporting by wireless. These telegrams also ought to include observations of the temperature and the salinity of the surface water.⁵

II. A special survey of the most important cold and warm currents and their regions of junction or conflict should be systematically maintained by cruises of research steamers fully equipped for meteorological and hydrographical observations.

III. The internal movements, both horizontal and vertical in the stratified water near the coasts should be followed by regular observations from a sufficient number of fixed stations and lightships along the coast line. The results should be compared with those from simultaneous hydrobiological observations (prevalence of fish eggs, larvæ, and fish food or plankton) and the yield of the local fisheries, both as regards quantity and quality, and also with observations of the local weather, the occurrence of fogs, and, in cold climates, the freezing of fiords and bights.

If the oceanographers and meteorologists of the United States, of Canada, and of Japan were to unite their efforts with those of northwestern Europe in research along these or similar lines we should undoubtedly soon be on the high road to new and startling scientific discoveries and also to results of the greatest practical value.

ON WORKING UP PRECIPITATION OBSERVATIONS.

A number of the younger station officials, enthusiastic in the development and discussion of meteorological data and particularly that relating to the rainfall of the country, have proposed projects of study that seem to indicate a lack of familiarity with the more fully devel-

oped methods of analysis of observational data and processes for eliminating defects or errors due to changes in methods or in observers or other things that bring about discontinuity in a long series of observations. In order to assist such students in the problem of discussing our rainfall observations, we offer the following translation of selected passages in Dr. Hugo Meyer's "Guide to the working up of meteorological observations for the benefit of climatology."¹ Although the original is over 25 years old, the methods presented are still standard and the principles stated are still regarded as fundamental.—Chief of Bureau.

HOMOGENEITY OF THE OBSERVATIONAL MATERIAL.

In working up or discussing meteorological observations the very first care of the student must be to determine the homogeneity of the series of observations he is using, i. e., to make sure that the changes in values (both periodic and nonperiodic) arise solely from changes in weather, and that he has excluded all those sudden or gradual changes which may arise from a change in exposure, or in instruments, or in instrumental constants, or from a change in the observer—changes that at times may be of as great a magnitude as a change in location of the station. Therefore, if one is not perfectly certain that the tabulations he desires to discuss in further detail, actually do present the march of the meteorological elements he should undertake to test the homogeneity of the different factors of the series. * * *

Although it really seems to be a matter of course that one should convince oneself of the homogeneity of a series of observations before undertaking further discussion of them; and although Schouw emphasized the point as early as 1827, yet the full bearing of this circumstance has not been fully appreciated until Hann's recent investigations into this point.² Hann has also shown the most convenient way for applying tests of homogeneity.

The method for testing the observational material from a station is based on the experience that radical changes in weather are rarely confined to a limited region, rather they take place with the same sign and with more or less equal intensity over extensive districts. Hence the differences [in the case of pressure or temperature] between simultaneous observations at neighboring points, are much more constant than the observed values themselves.

Accordingly the testing of the observations at a station involves a comparison of the first with the simultaneous observations at a neighboring standard station whose work is of guaranteed accuracy; or if no such standard station is available then the comparison is to be made with simultaneous observations at not less than two neighboring stations.

The first method for comparing the observational results on a meteorological element at different localities which are not too far apart is the graphic method. The means for all the years (or months) under consideration are plotted on coordinate paper, using the same scale for each station and arranging the corresponding values at all stations for the same year in the same vertical line; each pair of points for the same locality are then connected by a straight line. In this way one secures a number of broken lines corresponding to the number of stations brought together for comparison. In each of these lines the rises and falls seem to succeed each other without order. On comparing all the curves it must appear, however, that the succession of rises and falls is the same

¹ Meyer, Hugo. Anleitung zur Bearbeitung meteorologischer Beobachtungen für die Klimatologie. Berlin, Julius Springer, 1891. viii, [4], 187 p., 21½ cm. (Selections are from pp. 43-45, 51, 52, and pp. 132-140.)

² See in this connection Julius Hann. Untersuchungen über die Regenverhältnisse von Oesterreich-Ungarn. I. Theil: Die jährliche Periode der Niederschläge. Sitzungsber., Kaiserl. Akad. d. Wissensch., math.-naturw. Kl., Wien, 1879, 80-II, 571-635, particularly p. 573-578.

⁴ Pettersson, H. A recording current meter for deep-sea work. Quart. Jour. Royal Met. Soc., London, 1915.

⁵ This suggestion by the author has been included in a proposal for the reorganization of the Swedish Meteorological Service, presented to the Government by the Swedish delegates to the International Council for the Exploration of the Sea.